HYBRID COMBINED CYCLE POWER GENERATION FACILITY

Inventors: Paul Steinway

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates generally to a system for producing alternating current electric energy. More specifically, the invention describes a hybrid combined cycle power generation facility.

Description of the Prior Art

The production of alternating current electric energy is most frequently accomplished by converting thermal energy to mechanical energy that is then used to rotate the magnetic field of an electric generator. Commonly used thermal energy sources include fossil fuel combustion and controlled nuclear reactions. Controlled nuclear reactions and the combustion of fossil fuels are used to produce high pressure, high temperature steam that drives steam turbines. Those steam turbines in turn, convert the energy of the high pressure, high temperature steam to shaft horsepower and in so doing reject, or waste, a great deal of the thermal energy which enters the steam turbine. Conversion efficiencies of modern steam turbines are typically 28 - 32%. Thus, a large amount of the heat energy generated at the combustion stage is wasted rather than being converted to electric energy. Steam turbine electric generation facilities are relatively expensive to build and consume large amounts of water for cooling purposes. However, one advantage to such steam turbine facilities is that they have the ability to burn low cost solid fuels such as coal or biowaste. Unfortunately, steam turbine facilities that utilize such low cost fuels often produce large amounts of undesirable pollutants and therefore require costly pollution control technology to abate harmful, hazardous or unlawful emissions. In addition such facilities typically require additional permits, over and above the standard permits, for operation.

Fossil fuel combustion within internal combustion engines produces thermal energy in the form of high temperature, high pressure air which is converted to shaft horsepower. Much like steam turbines, internal combustion engines waste most of the thermal energy released by the combustion process. Different internal combustion technologies, e.g., combustion turbines or reciprocating engines, have different thermal energy utilization characteristics, but the conversion efficiencies of internal combustion engines seldom exceed 40%. When compared to steam turbine technology, however, modern combustion turbine facilities are less expensive to build, use less

water, have better conversion efficiencies and are capable of lower pollution emission rates than steam turbine facilities. However, combustion turbines usually require higher cost liquid and gaseous fuels, such as refined oil products or natural gas.

A majority of the thermal energy released during the combustion process in turbines is wasted in the form of hot exhaust gases. It is possible to improve the overall conversion efficiencies of these turbines by capturing a portion of the thermal energy present in the combustion turbine exhaust flow. Heat recovery devices located in the hot exhaust flow can be used to produce steam that is directed to a conventional steam turbine used to generate additional electric energy. The use of combustion turbines with exhaust recovery devices and downstream steam turbines is referred to as "combined cycle" technology. Modern combined cycle power generation facilities are capable of conversion efficiencies in excess of 50% with some developing technologies nearing the 60% threshold.

There are two basic or fundamental types of combustion turbines available for use in power generation facilities: industrial turbines and aeroderivative turbines. Industrial turbines are very robust machines designed to provide highly reliable service in ground based operations driving machinery such as compressors, pumps and electric generators. Industrial turbines tend to be very large and offer good steady-state operating characteristics but exhibit limited tolerance for frequent start/stop cycles, which subject the massive turbine to rapid thermal cycles. Typically, industry design requirements for industrial turbines emphasize high temperature and high load tolerance for extended periods of time with secondary consideration for overall weight. One drawback of industrial turbines is that their large size and heavy weight necessitate in situ disassembly and re-assembly which results in extended outages for routine maintenance. Aeroderivative turbines, on the other hand, are often characterized by cutting edge technology to maximize power-to-weight ratios, quick starting times, high fuel efficiency and high start/stop cycle tolerance, all of which are important features since this type of turbine is most often used in aircraft propulsion systems. Materials and components design in aircraft turbines emphasize high strength and low weight with secondary consideration for long term component life. Because they are lightweight and small, aeroderivative turbines are easily removed and repaired off site when routine repair or refurbishment is required. When removed, the turbine is quickly and easily replaced by a spare turbine thus reducing production outages for routine maintenance. However, one drawback to aeroderivative

turbines in relation to industrial turbines is that aircraft turbine technology is more expensive and less robust than industrial turbine technology.

Both industrial and aircraft turbine technologies are used in modern electric energy generating facilities described above. Both technologies can be found in simple cycle, combustion turbine generator facilities and in combined cycle power generation facilities utilizing combustion turbines, exhaust heat recovery and steam turbines. Steam and gas ("STAG") combined cycle systems are well known in the industry. These systems typically comprise gas turbines, steam turbines, generators and heat recovery steam generators ("HRSG"). In any event, these prior art power generation facilities have limited the use of combustion turbines to either industrial turbines or aircraft turbines, but not both.

It would therefore be desirable to have a power generation facility that has the advantages of both an industrial turbine, namely low pollution emissions levels, low capital cost, superior thermal efficiencies, and robust construction, and an aeroderivative turbine, namely rapid response to varied production levels with high thermal efficiencies and quick maintenance turn arounds.

SUMMARY OF THE INVENTION

The present invention relates to a system and facility for generating alternating current electric power in which a hybrid, combined cycle power generation facility is provided, including at least one industrial gas turbine, at least one aeroderivative gas turbine. Such a facility results in lower costs of construction and capital expense and lower costs of production as compared to a combined cycle facility using only aeroderivative turbines. Similarly, the present invention results in a facility that has faster and lower cost start/stop capabilities and better part load fuel efficiencies than combined facilities using only industrial turbines.

In a typical configuration, at least one aeroderivative ("AD") turbine is provided. The AD turbine powers a suitable generator and may further provide heated exhaust gas to a heat recovery steam generator, which in turn feeds high pressure, high temperature steam to a steam turbine. The steam turbine also powers a generator. By using an AD turbine, the power system may be brought online quickly to begin producing power. The HSRG recovers heat from the exhaust gas of the turbine and uses the heat to generate steam to power the steam turbine. In this way, the efficiency of the system may be greatly increased.

The system also includes at least one industrial gas ("IG") turbine. The IG turbine typically takes longer to spin up and be brought online, however, once in operation, it is generally capable of

higher and more stable output than an AD turbine. As with the AD turbine, the IG turbine has an associated HRSG in thermodynamic communication therewith, to recover heat from the exhaust gas of the turbine to generate steam for a steam generator. The IG turbine also powers a suitable generator.

The HRSG's, each of which is associated with either an IG or AD turbine, use heated exhaust gas from the turbines to generate steam. This steam is then fed to the steam turbines, which in turn power additional generators. This creates a much more efficient system that using gas turbines alone. Additionally, the HSRG's may include supplementary firing equipment to produce additional high pressure, high temperature steam and offer additional operational flexibility.

The advantage of the system of the present invention over the prior art systems is that it draws on the benefits of each type of turbine mentioned herein, while diminishing the drawbacks associated with each type of turbine. For example, the AD turbine is able to begin producing power in a relatively short amount of time. Therefore, it can be used to provide power quickly when the system is initially started, while the bigger IG turbine and steam turbine are brought on-line. Both the IG turbine and the steam turbine are capable of producing a greater power output, however, as compared to the AD turbine. Thus, once spun up, the IG turbines and steam turbines can be utilized for a substantial portion of the on-going power production system. The AD turbine may also be used intermittently, for instance, during peak load periods. In this way, the IG and steam turbines may be operated for longer periods of time without the need to vary output. The AD turbine may be used intermittently to provide additional power as necessary. When included in the system design, supplementary firing in the HRSGs provides smooth load transitions while starting and stopping both AD and IG turbines. Supplementary firing also can be used to produce additional high pressure steam for additional steam turbine generator output. Operation with full supplementary firing is reserved for peaking conditions when the resulting decrease in thermal efficiency is secondary to maximum capacity production.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows a typical prior art industrial turbine, combined cycle power generation facility.

Figure 2 is a schematic of a typical prior art aeroderivative, combined cycle power generation facility.

Figure 3 is a schematic of a combined cycle power generation system of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

As shown in Figs. 1and 2, a typical power generation facility may include an industrial turbine, a heat recovery boiler or steam generator, and a steam turbine or may include an aeroderivative turbine, an HRSG and a steam turbine. Each facility has certain, previously enumerated advantages and disadvantages, however, the present invention includes many of the advantages and overcomes many of the disadvantages of the prior art systems.

Fig. 3 shows a schematic of a system of the present invention. While those skilled in the are will understand that any number of turbines can be utilized, a first industrial gas turbine is provided for turning or driving a first generator. The IG turbine may be any suitable turbine, but is preferably General Electric Frame 7 EA or Frame 7 F. A fuel system provides the IG turbine with a suitable fuel for combustion, such as natural gas or refined oil products. The exhaust gas from the IG turbine are fed via suitable conduit or duct to a first HRSG unit.

A second, aeroderivative turbine is provided for turning or driving a second generator. Again, it is the combination of an aeroderivative turbine with an industrial turbine that is unique and those skilled in the art will understand that any number of turbines can be utilized. The fuel system provides a suitable fuel supply for the AD turbine. Typically, the AG turbine burns natural gas or refined oil products. Exhaust gas from the AD turbine is passed via suitable conduit or duct to a second HSRG unit. In a preferred embodiment, the AD turbine is a General Electric LM6000 aeroderivative turbine.

The system of the invention preferably includes at least one HRSG. In one embodiment, an HRSG is provided for each gas turbine, however, it should be understood that multiple gas turbines may be exhausted into a single HRSG. The HRSG units convert the excess, unused energy (in the form of heat and unburned fuel) from the gas turbines into high pressure, high temperature steam, which may be used to drive a steam turbine. This greatly increases the efficiency of the system. In a preferred embodiment, the HSRG's may have supplementary firing equipment installed therein. This additional equipment typically includes burners which further aid in heating and pressurizing steam for the steam turbines. The burners may be fueled, for instance, with natural gas or refined oil products or may use other fuels such as heavy oil or coal. The use of supplementary firing equipment may increase the output of the steam turbines by as much as 100% and may increase the

overall system output by 30%. A water supply system provides water to the HRSG's for the production of steam. Preferably, the water supply system provides demineralized water.

In an alternative embodiment, the HRSG's may be unfired or lack supplementary firing equipment. This may decrease capital and maintenance costs. In this configuration, the HRSG merely transfers heat from the hot turbine exhaust gas to water or steam via convective heat transfer.

The steam produced in the HRSG units is passed, via suitable duct or conduit, to a steam turbine. The steam turbine drives or turns a third generator. Any number of steam turbines may be used, depending, for instance, on the number of gas turbines and HRSG units in the system.

In operation, the present system provides an aeroderivative turbine which may be put into service or brought online in a relatively short amount of time. This allows the system to generate electric power, albeit at a somewhat decreased capacity, shortly after the system is started. The exhaust from the AD turbine is ducted to an HRSG to begin steam production for the steam turbine. Since a typical steam turbine operating on steam produced in part using waste gas from an IG turbine cannot begin to operate until the IG turbine is spun up, the system of the invention also permits use of the steam turbine at an earlier stage of the power production process, as compared to the prior art systems. The system preferably includes suitable monitoring and control equipment to determine when the HRSG's are producing sufficient steam to start the steam turbines. Until that time, the steam generated is trapped within the HRSG or vented to atmosphere. At the same time the AD turbine is started, an industrial gas turbine is also started. These relatively bigger IG turbines require a longer time to reach proper operating conditions, as compared to the AD turbines. However, once these IG turbine begins to generate power, their power output can greatly exceed that of the AD turbine. The exhaust from the IG turbine is also ducted to a corresponding HRSG to further provide steam to power the steam turbine. Once the HRSG's are producing sufficient steam, the steam turbine may be brought online.

Depending on the level of power output required by the system at any given time, the AD turbine may be shutdown after the IG turbine and/or the steam turbine are online. Preferably, the AD turbine is used to provide relatively quick power output when the system is first started, such as after a maintenance shutdown, during initial system startup, or as required to produce daily peak output to follow typical electric consumer use profiles. In this way, the IG and steam turbines may be operated in a relatively long term capacity and at near constant output level(s). This decreases wear and subsequent maintenance intervals with regard to these turbines. The AD turbine may then

be used to provide variable additional power when demand on the system is high. The AD turbines may also be left online during shutdown of the IG turbine in order to keep the HRSG's in a state of hot stand by for enhanced system start/stop cycling duty capabilities.

Thus, the system of the present invention is uniquely suited to provide adequate power during high or peak power demand, but does not generate excess power during low demand periods. By using AD turbines to boost system output during the peak periods, the larger IG and steam turbines do not require undesirable fluctuation of their output levels. This near constant, stable output level increases both the stability and longevity of the system as a whole, thereby requiring less maintenance and lowering expenses associated therewith.